The current in the vertical lifting loops **61** is induced only as the train passes over each individual loop in the array and continues to flow therein for a short period after the train passes. The current dies down very soon after the train passes by, and in effect the track array of vertical lifting loops **61** carries no current ahead of or behind the train.

It is important for a stable suspension that, since the magnetic force exerted on the train varies with its position, a restoring force be generated which always tends to return the train to an original equilibrium position regardless of the direction of displacement. Even if the suspension itself be stable, the train can still oscillate like a spring if perturbations are not damped out. Therefore it is a necessary condition for stability of the train suspension system that any oscillations, as well as any displacements, be counteracted so that the train will be quickly returned to its equilibrium position. It is readily apparent that the suspension is vertically stable for, as described previously, the weight of the train causes the vehicle to assume and maintain a vertical equilibrium position *e* (FIG. 3) where the electromagnetic coupling between the train current loops **55** and the track loops **61** generates a gravity-offsetting lift force.

For horizontal, lateral, stability of the train, as it moves longitudinally down the track bed, an additional loop array **63** is provided on each side of the track bed structure **70** as shown in FIGS. 5–7. Each of the left and right arrays **63** is comprised of two longitudinally-extending series of horizontally-disposed top loops **63T** and bottom loops **63B**. Similar to the vertical lifting loops, the individual loops in the horizontally stabilizing array **63** are of short length relative to the longitudinal dimension of a train loop **55**, so as to maximize the inductive interaction therebetween. Horizontal stability track loops **63T** and **63B** are electrically independent of each other and either or both can be used as a means for providing horizontal restoring force, depending on the amount of horizontal stabilization desired.

As shown in the figures, each of the horizontal stability loops, forming the horizontal stability track array **63**, is in the form of two rectangular sections, electrically cross-connected in a figure-8 configuration. This construction serves to establish a horizontal equilibrium position for the train superconductor loops **55** in which no net current is induced in the stabilizing track loops. In other words, with the arrangement of FIGS. 5–7, the horizontal stability loops **63** and the train superconducting loops **55** coact such the magnetic flux field of the train loops induces equal and opposite voltages in the respective half-sections forming the individual track loops of array **63**. Thus no net current results in the track loops so long as the lateral position of the train loop **55** remains symmetrically located about the vertical plane of symmetry *v* of the track loops **63**. If the train should move in either horizontal direction relative to the track bed, one-half section of each of the horizontal stability loops **63** would be more tightly coupled to the train superconductor loop **55** than its mate. This, in turn, would induce a net unbalanced voltage in each of the respective track loops, thereby producing a circulating current whose concomitant magnetic field would provide a restoring force interacting with that of the train loops so as to return the train body to the equilibrium position *v*.

Unlike the operation of the lift track loops **61** in which current circulates continuously for the time that each track portion is adjacent the field generated by train loops **55**, the horizontal stability loops **63** have no current induced therein except when the train body is displaced from the vertical plane of symmetry *v*. The magnetic restoring force generated in the horizontal stability loops **63** is comparable in magnitude to that generated by the vertical lift loops **61**. The horizontal restoring force exerted on the train will maintain the vehicle, within a few inches at most, over the center of the road bed 25 and will effectively counteract any sidewise displacement forces, e.g., inertial effects or wind, likely to be experienced by the train while in motion. It has been calculated that, for the system characteristics previously stated, a three-inch displacement of the train from vertical symmetry plane *v* would require a horizontal displacement force equal to the entire weight of the train.

In addition to possessing vertical and horizontal stability, it is also important that the train system be provided with means for insuring adequate stability against oscillatory motion. For this purpose an array of damping track loops **65** are provided on each side of the track bed as shown in FIGS. 8–10. The damping track loop array **65** on each side of the track bed is comprised of two longitudinally extending series of loops: a first set of horizontally disposed loops **65H** for damping horizontal oscillations, and a second set of horizontally disposed loops **65V** for damping vertical oscillations.

Instead of two sets of loops providing separate horizontal and vertical damping, it is possible, but somewhat less effective, to use a single longitudinally extending set of loops on each track side oriented at a 45° angle to damp oscillations in both directions. Indeed, some vertical and horizontal damping is inherently provided by loops **61** and **63**, respectively.

Unlike lifting loops **61** and lateral stability loops **63**, which were quite short compared to the length of the train body, the circuit path for each of the damping loops **65** extends longitudinally for a considerable number of train lengths, perhaps ten or more. Thus the damping loops respond to transient oscillations or sudden perturbations of the train, rather than responding to gradual changes in displacement as the train follows a winding or sloping track bed.

As indicated in the front sectional view of FIG. 9, the two sets of horizontal and vertical damping loops **63H** and **63V** are arranged so that their conductors are aligned in the horizontal and vertical planes, respectively, of the conductors forming the superconducting train loops **55**. Thus damping loop **63H** is coplanar with train loop **55**, and laterally displaced therefrom; damping loop **65V** lies in a plane parallel to that of train loop **55** and substantially directly opposite train loop **55**. This maximizes the coupling therebetween. Because of the long length of the damping loops relative to the length of the train, and because of the tight coupling which exists between the damping loops and the train loops, the currents in the damping loops in the track regions immediately ahead and immediately behind the train are not zero.

The damping loop currents are of changing value, produced in response to transient perturbations in the train motion, and generate electromagnetic restoring forces which interact with the primary field of the train loops to quickly dampen oscillatory motions of the train. By suitable selection of the resistance, inductance, and length of the damping loops **65**, the degree of damping can be adjusted to the level desired, so that all oscillations and similar transient perturbations can be attenuated very rapidly. To achieve an effectual damping action, it is importnt that a net magnetic flux field be generated by the train loops on each side of the vehicle. The number of alternately polarized superconducting magnets **55**, on each side of the train body, should either total an odd number or their respective magnetic fields should be non-equal. This produces a net resultant magnetic flux field for the train body as a whole, which can be coupled to that of damping loops **65**.

FIG. 11 is a front sectional schematic view showing the lifting, horizontally stabilizing and damping track loop arrays of FIGS. 2–10, with all combined in a track bed structure **70** to form a complete electromagnetic suspension and stabilizing system for a train according to the present invention. The track structure **70**, which is symmetrical about a vertical centerline, contains in its left and righthand tracks the following track loop arrays: